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(54) Printing apparatus

(57) A printing apparatus adapted to eject ink droplets from ink ducts, comprising at least one ink duct (5) provided with an electromechanical transducer (2), a drive circuit (3) provided with a pulse generator (4) to energise the said transducer (2), and means for detecting breakdown of the ink duct without interrupting the operation of the printing apparatus ("on the fly"), comprising a measuring circuit (7) for measuring an electrical signal generated by the transducer (2) in response to energisation, and switching means (8) to break the circuits in such manner that the drive circuit (3) is open if the measuring circuit (7) is closed.

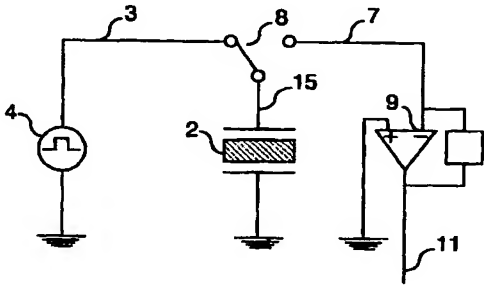

FIG. 3

EP 1 013 453 A2

Description

[0001] The invention relates to a printing apparatus adapted to eject ink droplets from ink ducts, comprising at least one ink duct provided with an electromechanical transducer, a drive circuit provided with a pulse generator to energise the said transducer, a measuring circuit for measuring an electrical signal generated by the transducer in response to energisation, and means to break the circuits in such manner that the circuit is open if the measuring circuit is closed.

Printing apparatus of this kind is known from US 4 498 088. In this printing apparatus, which is of the "drop-on-demand" type, the drive circuit applies an electrical pulse across the electromechanical transducer, more particularly a piezo element, so that this transducer is energised and generates a pressure wave in the ink duct. An ink droplet is ejected from the ink duct as a result. To guarantee reliability of such printing apparatus, means are provided to detect breakdown of the ink duct, e.g. due to the presence of an air bubble in said duct. These means form part of a measuring system and comprise a measuring circuit with which it is possible to measure the resulting vibration in the ink duct after a pressure wave has been generated by the transducer. For this purpose, the transducer is used as a sensor: a vibration in the duct in turn results in deformation of the electromechanical transducer, so that it generates an electrical signal. If air bubbles are present in the duct, this results in another vibration and consequently another electrical signal. Breakdown of an ink duct can thus readily be detected by measuring the electrical signal. A repair operation for the duct in question can then be carried out. One important disadvantage of a printing apparatus of this kind is that in order to check the condition of the ink ducts, the printing apparatus must leave the normal printing mode, i.e. the mode in which at least one ink duct ejects ink droplets for generating an image on a substrate, to pass to a measuring mode. In the measuring mode the transducer is energised so that the ink duct is vibrated but it is not possible to achieve ejection of an ink droplet from that duct. The resulting electrical signal is measured, and after this it is possible to determine whether there are any air bubbles in the ink duct. After the ink duct has been checked, the printing apparatus is returned to the printing mode, possibly after a repair operation has been carried out. The need to switch between a printing mode and a measuring mode results in a loss of productivity of the printing apparatus. Productivity will further fall with increasing reliability requirements for the printing apparatus, which means that the interval of time between the measuring modes has to be reduced. In addition to loss of productivity, the known printing apparatus has the disadvantage that two drive circuits provided with pulse generators are required for the transducer: one driv circuit to energise the transducer when the printing apparatus is in a printing mode, and a drive circuit to energise the transducer when it is in a measuring mode. This not only makes the printing apparatus expensive, but also, due to the increase in the number of components, less reliable. The object of the invention is to obviate these disadvantages. To this end, a printing apparatus has been invented wherein measurement of the electrical signal generated by the transducer in response to energisation takes place when the printing apparatus is in a printing mode. There is therefore no need to interrupt the printing mode. The electrical signal is measured immediately after the transducer has been energised, the energisation being such that an ink droplet is ejected with the duct operating as normal, in order to generate an image on a substrate. As a result there is no loss of productivity and in addition only one drive circuit is required for the transducer. An additional advantage is that the breakdown of the ink duct can be detected practically immediately, so that in many cases a repair operation can be carried out before any visible artefacts have appeared in an image. This means that a printing apparatus according to the invention has a very high reliability. In one preferred embodiment the drive circuit and the measuring circuit are connected to the transducer via a common line serving as an input and output for electrical signals. This has advantages when the print-head is provided with a large number of ink ducts. The circuit can further be simplified by breaking the circuits by means of a changeover switch, so that the drive circuit is automatically opened as soon as the measuring circuit is closed. This changeover switch can be embodied by known electrical means but can also be integrated in the drive IC. To check whether a vibration in the duct differs from a normal vibration, i.e. from a vibration when the duct operating properly, the electrical signal generated by the transducer in response to energisation can be compared with the electrical signal generated by a dummy element having the same impedance as the transducer in response to a comparable energisation. Since, however, it is difficult to find a dummy element having in all circumstances exactly the same impedance as the transducer, it is preferable not to compare the electrical signal with a signal generated by a dummy element, but to characterise the electrical signal itself. For this purpose, at least one wave characteristic selected, for example, from the group comprising: amplitude, zero-axis crossing, frequency, phase and damping should be determined. It has surprisingly been found that in this way deviation in an ink duct can be detected with much higher accuracy. In this way it is not only possible unambiguously to determine what is the cause of malfunctioning of the ink duct (whether an air bubble, a solid particle clogging the duct, or a mechanical fault in the piezo element and so on) so that a repair operation can be accurately adapted to such cause, in addition a small deviation can be found which at that time is not yet affecting the ejection of ink droplets, for example an air bubble which is too small or still too far away from the opening of the ink duct to prevent

ejection of an ink droplet. This enables preventive repair of an ink duct, so that generally there should be no artefacts appearing in an image. This is a considerable contribution to the reliability of the printing apparatus. In one preferred embodiment, a measured wave characteristic is compared with a reference value so that it is possible to determine easily whether a repair operation is required. In order further to increase the sensitivity of the measuring circuit, it can be provided with an amplifier. If an input of the amplifier is connected to the printing apparatus earth, stray capacitances (e.g. in the wiring) and leakage currents will also have hardly any effect on the measurement of the electrical signal generated by the transducer, so that the measurement accuracy further increases. In view of the simplicity of the measuring circuit in the printing apparatus according to the invention it is possible to provide a separate measuring circuit for all the transducers in the printing apparatus, even if there are several hundred. This makes it possible to check each duct, after an ink droplet has been ejected, for correct operation thereof, so that maximum reliability can be guaranteed.

[0002] The invention will now be explained with reference to the examples hereinafter.

Fig. 1 is a diagram of the main components of a printing apparatus provided with ink ducts.

Fig. 2 is a diagram of an ink duct provided with an electromechanical transducer.

Fig. 3 is a block schematic of the electromechanical transducer, the drive circuit and the measuring circuit in a preferred embodiment.

Fig. 4 is a diagram showing how the circuits can be switched.

Fig. 5 shows a number of electrical signals generated by a transducer according to the condition of the ink duct.

[0003] Fig. 1 shows a printing apparatus provided with ink ducts. In this embodiment, the printing apparatus comprises a roller 10 to support a receiving medium 12 and guide it along the four printing heads 16. The roller 10 is rotatable about its axis as indicated by the arrow A. A carriage 14 carries the four print-heads 16, one for each of the colours cyan, magenta, yellow and black, and can be moved in reciprocation in the direction indicated by the double arrow B, parallel to the roller 10. In this way the print-heads 16 can scan the receiving medium 12. The carriage 14 is guided on rods 18 and 20 and is driven by suitable means (not shown). In the embodiment as illustrated in the drawing, each print-head 16 comprises eight ink ducts, each with its own outflow aperture 22, said ducts forming an imaginary line perpendicular to the axis of the roller 10. In one practical embodiment of a printing apparatus, the number of ink ducts for each print-head 16 will be many times greater. Each ink duct is provided with an electromechanical transducer (not shown) and associated drive circuit. In this way, the ink duct, transducer and drive circuit form a unit which can serve to eject ink droplets in the direction of the roller 10. If the transducers are energised image-wise, then an image forms, built up from ink droplets, on the receiving medium 12.

[0004] In Fig. 2, an ink duct 5 is provided with an electromechanical transducer 2, in this example a piezo element. Ink duct 5 is formed by a groove in baseplate 1 and is defined at the top mainly by piezo element 2. At the end the ink duct 5 merges into an outflow aperture 22 formed by a nozzle plate 6. When a pulse is applied across piezo element 2 by pulse generator 4 via the drive circuit 3, said element generates a pressure wave in ink duct 5 so that an ink droplet is ejected from the outflow opening 22.

[0005] Fig. 3 is a block schematic diagram of the electromechanical transducer 2, the drive circuit 3 and the measuring circuit 7 in a preferred embodiment. Drive circuit 3 provided with pulse generator 4, and measuring circuit 7 provided with amplifier 9, are connected to piezo element 12 via a common line 15. The circuits are opened and closed by changeover switch 8. After a pulse has been applied across the piezo element 2 by the pulse generator 4, element 2 in turn experiences a resulting vibration in the ink duct, and this is converted to an electrical signal by element 2. If, after termination of the pulse, changeover switch 8 is so switched as to close the measuring circuit, the said electrical signal is discharged through the measuring circuit 7. Amplifier 9 amplifies this signal which is fed via output 11 to an interpretation circuit (not shown), which if required may be followed by an action circuit (not shown).

[0006] Fig. 4 shows how the circuits 3 and 7 could be switched. During a drive period A the drive circuit 3 is closed so that piezo element 2 can be energised. After energisation has taken place, a measuring period M starts, in which measuring circuit 7 is closed via changeover switch 8 and drive circuit 7 is opened. After expiry of measuring period M, in which the electrical signal generated by piezo element 2 is measured, the drive circuit is closed and a new drive period A starts. Of course there are many variants of this switching procedure. For example, a measuring period M could also follow after the piezo element has been energised a number of times in a drive period. In an embodiment in which very high reliability is required, each duct could be checked after each pulse. If a repair operation is necessary, it can be restricted to the duct in which the malfunctions occur. Of course it is possible to check the functioning of an ink duct during the repair operation as well and to stop this operation as soon as the duct operates properly again. If reliability is less important, it could be decided, for example, to check one jetting duct for each jet pulse. It would also be possible to check a duct after a fixed number of ejected ink droplets or aft r a specific interval of time.

[0007] Fig. 5 shows a number of electrical signals

as generated by a transducer in response to a pressure wave in an ink duct, dependent on the state of said ink duct. If an ink duct is operating properly, the result is an damped sinusoidal electrical signal as shown by curve 1. For a given ink duct geometry, the presence of an air bubble results in an electrical signal as shown in curve 2. This signal has a higher frequency, higher initial amplitude and weaker damping. If a duct is (partially) closed by a solid particle, then for the same duct geometry this results in an electrical signal having a lower frequency, smaller initial amplitude and stronger damping as shown in curve 3. Finally, curve 4 is an example of an electrical signal measured in the case of a specific mechanical deviation of the piezo element.

It will be apparent from the foregoing that the cause of the malfunctioning of an ink duct (or the expected malfunctioning) can be accurately determined in a printing apparatus according to the invention so that it is possible to adapt the repair operation to such cause.

The measurement can be used, for example, to check the operation of the individual ducts after production of a print-head provided with one or more such ducts. If errors have occurred in production, e.g. a layer of glue that has worked loose, a scratch in a wall of a duct, a faulty piezo element etc.; these faults are recognised and can be repaired if possible.

In the case of a printing apparatus in use, the measurement can be used to check the state of the ink ducts (continuously) without any loss of productivity. The high accuracy with which irregularities in an ink duct can be detected even makes it possible to carry out preventive repairs on ducts, i.e. before there is any question of failure of an ink duct.

[0008] In a preferred embodiment of the printing apparatus, one or more wave characteristics of the electrical signal as shown in Fig. 5 are compared with a set of reference values which in a practical embodiment are provided with top and bottom limits within which a wave characteristic of a normally operating duct should be located. The reference values can be determined in many ways, but this is not an essential part of the invention. For example, the reference values can be determined after completion of the production process of a print-head. In addition, the reference values could be determined when the printing apparatus is in operation, by taking the average over a large number of pulses. In this way it is possible to adapt these values continuously, so that, for example, (slow) wear processes in the print-head have no adverse influence on the measurement. It is also possible to compare the wave characteristics of an individual duct with those of one or more (neighbouring) ducts.

The invention is not limited to the embodiments described. Modifications can easily be made by the skilled man. For example, the required reliability in relation to the productivity of the printing apparatus depends, inter alia, on the way in which the reference values are determined, and whether this is carried out for each individual duct or for all the ducts together, how far apart the top and bottom limits of the reference value are situated, how many wave characteristics are determined to establish the condition of a duct, and so on.

Claims

1. A printing apparatus comprising
   - at least one ink duct (5) provided with an electromechanical transducer (2),
   - a drive circuit (3) provided with a pulse generator (4) to energise the said transducer (2),
   - a measuring circuit (7) to measure an electrical signal generated by the transducer (2) in response to energisation,
   - means for breaking the circuits in such manner that the drive circuit (3) is open if the measuring circuit (7) is closed,

   characterised in that measurement of the electrical signal takes place when the printing apparatus is in a printing mode.

2. A printing apparatus according to claim 1, characterised in that the drive circuit (3) and the measuring circuit (7) are connected to the transducer (2) via a common line (15).

3. A printing apparatus according to claim 2, characterised in that the means for breaking the circuits comprise a changeover switch (8).

4. A printing apparatus according to any one of the preceding claims, characterised in that at least one wave characteristic is determined of the electrical signal generated by the transducer (2).

5. A printing apparatus according to claim 4, characterised in that the wave characteristic is selected from the following group: amplitude, zero-axis crossing, frequency, phase and damping.

6. A printing apparatus according to claim 4 or 5, characterised in that the wave characteristic is compared with a reference value.

7. A printing apparatus according to any one of the preceding claims, characterised in that the measuring circuit is provided with an amplifier (9).

8. A printing apparatus according to claim 7, characterised in that one input of the amplifier (9) is connected to the printing apparatus earth.

9. A printing apparatus according to any one of the preceding claims, characterised in that the said electrical signal is measured after each energisation of the transducer (2).

10. A printing apparatus according to any one of the preceding claims, characterised in that each transducer is provided with a measuring circuit (7).

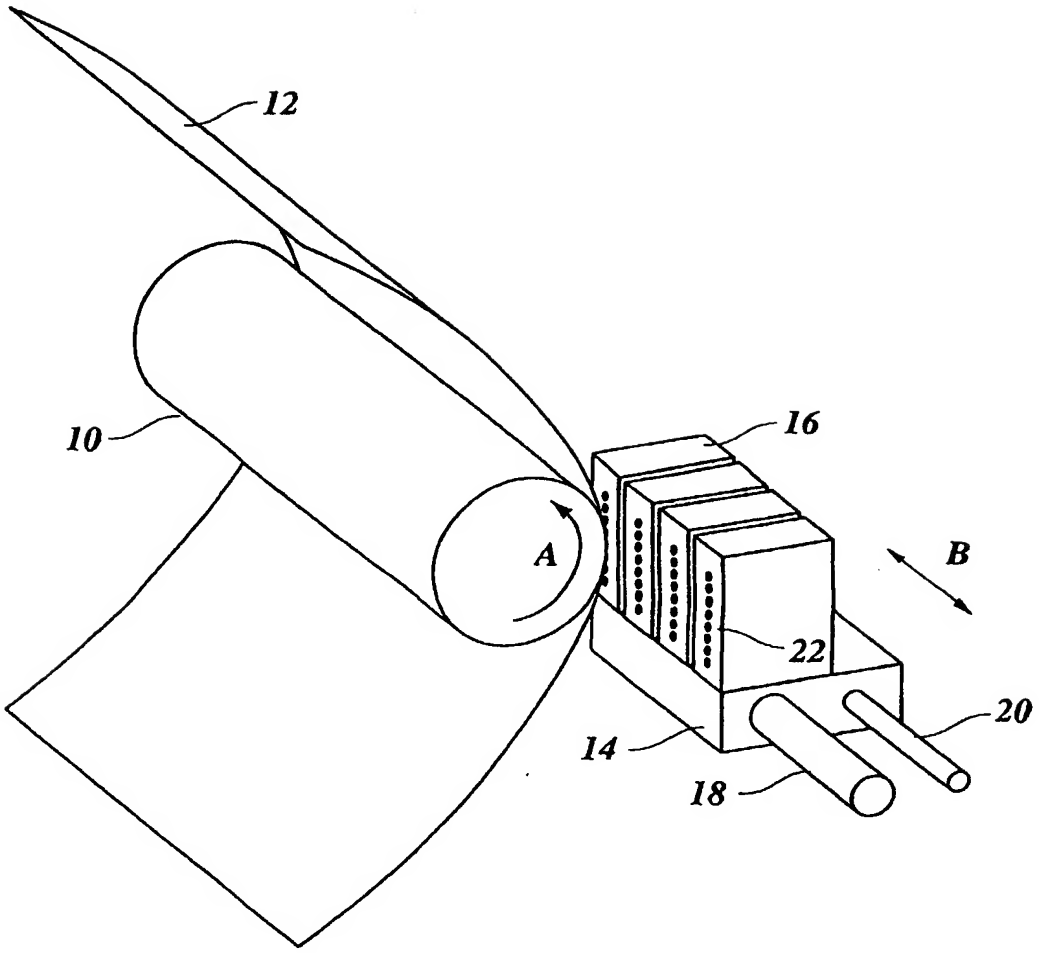

FIG. 1

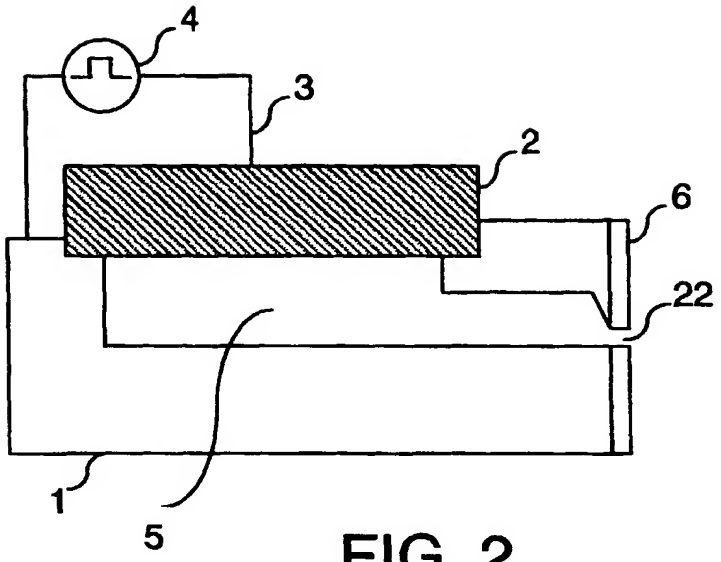

FIG. 2

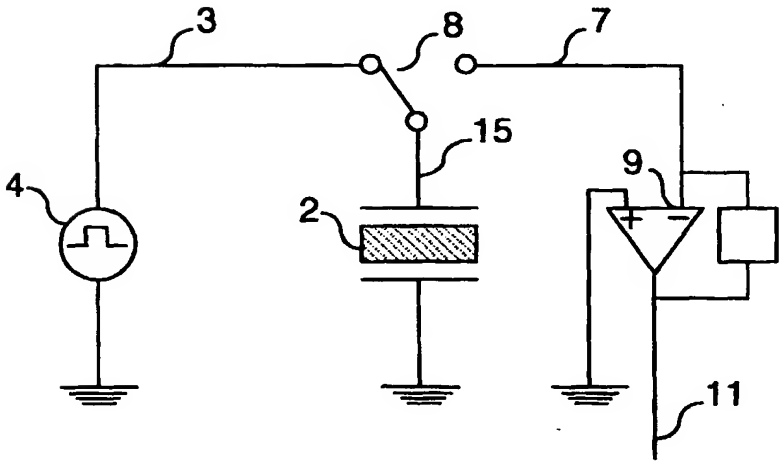

FIG. 3

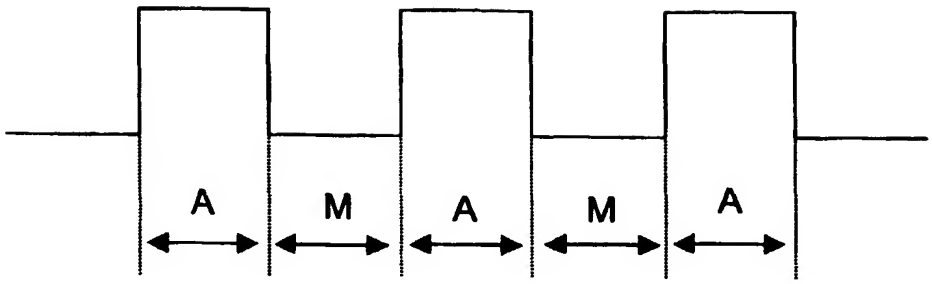

FIG. 4

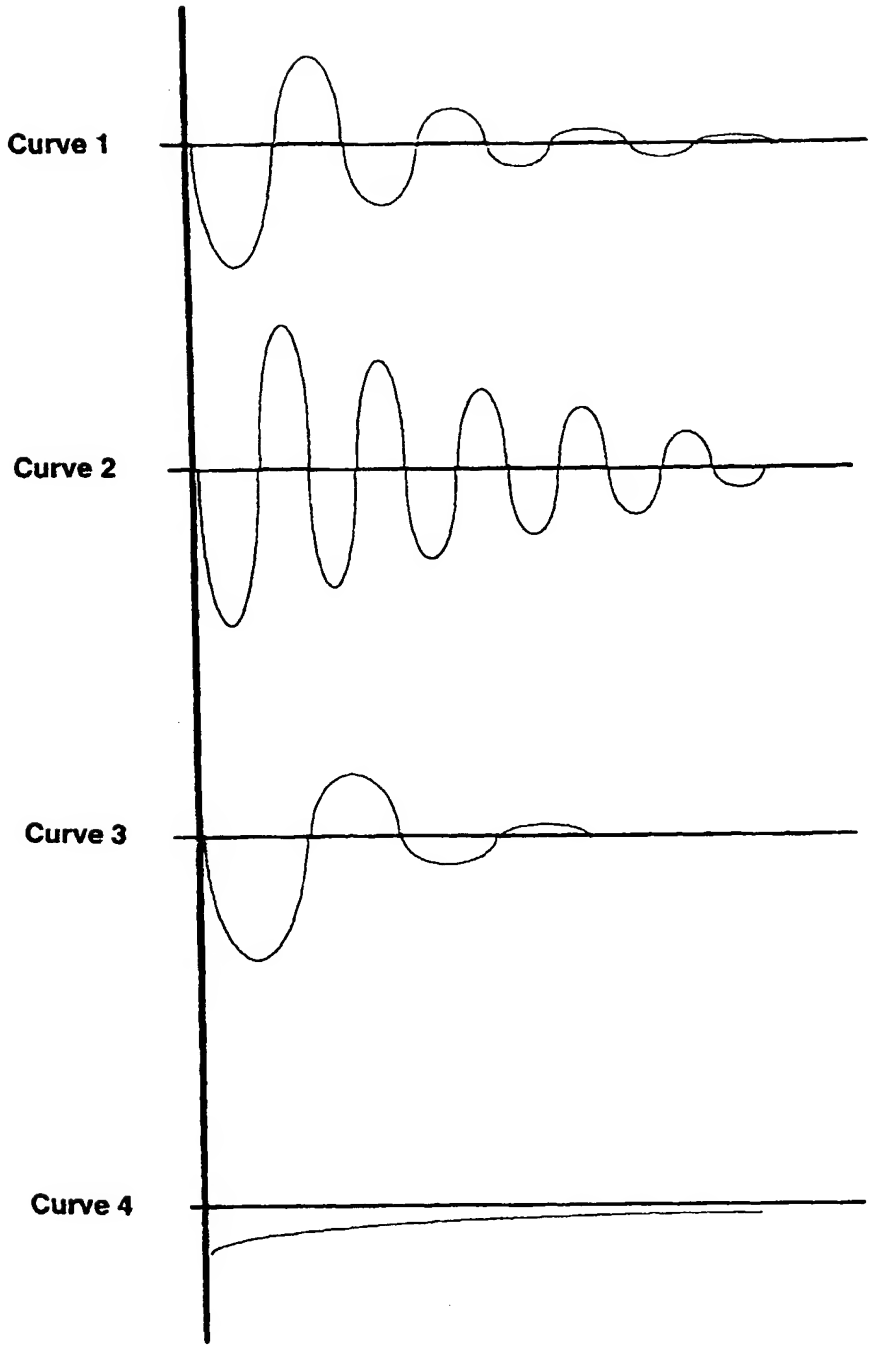

FIG. 5